Meteo 431 Atmospheric Thermodynamics Spring 2002

Problem set # 9

assigned: 17 April 2002

due: 24 April 2002

1. B&A, Chapter 6, #3.

2. B&A, Chapter 6, #5. (hint: What temperature is the lowest temperature that air can be cooled by evaporation? Use the skew-T.)

3. B&A, Chapter 6, #6.

4. B&A, Chapter 6, #8.

5. B&A, Chapter 6, #22

6. B&A, Chapter 6, #24.

Meteo 431 Spring 2002

Problem Set #9

(1.) B&A, #3 For 400% RH to have clouds form,

$$e_s^{new}(T_n) = 4\, e_s(T_d) \Rightarrow \exp\left(-\frac{l_v}{R_v T_n}\right) = 4 \exp\left(-\frac{l_v}{R_v T_d}\right)$$

$$-\frac{l_v}{R_v T_n} = \ln 4 - \frac{l_v}{R_v T_d} \Rightarrow -\frac{l_v}{R_v} T_d = T_n T_d \ln 4 - \frac{l_v}{R_v} T_n$$

$$T_n = \frac{l_v}{(l_v - \ln 4\, R_v T_d)} \cdot T_d = \frac{2.5\times10^6}{2.5\times10^6 - 639\,T_d} \cdot T_d$$

$$\Delta T = T_n - T_d = \frac{639\, T_d^2}{2.5\times10^6 - 639\, T_d}$$

for $T_d = 290$ K, $\Delta T = 23$ K

for $T_d = 300$ K, $\Delta T = 25$ K

$T_d = 270$ K, $\Delta T = 20$ K

Since Γ_d is unchanged, and T must now drop ~20-25 K more, the LCL increases by 2 to 2.5 km.

We can do this on a skew-T by choosing a ws that is 4 times greater than normal. If we assume T=10°C @ 1000 hPa, then ws= 7.5 g/kg implies we need a <u>new</u> wsn = 30 g/kg. (T=29°C)

If Td = 273 K, then <u>old</u> LCL = 860 hPa (1.4 km)

now, take T=29°C, and Td=0°C @ 1000 hPa

to get new LCL = 630 hPa (3.7 km)

$\Delta h \sim 2.3$ km, in line with the other estimate.

(2.) B&A, Ch6, #5. Assume very dry means RH = 10%

If $T = 40°C$, $w_s = \frac{\varepsilon e_s}{p - e_s}$ & $e_s = 6.11 \exp\left\{6808\left(\frac{1}{273} - \frac{1}{313}\right) - 5.09 \ln\left(\frac{313}{273}\right)\right\}$

$e_s = 73.8\text{ hPa} \Rightarrow w_s = 50.\text{ g/kg} \Rightarrow w = 5\text{ g/kg}$

- The lowest temperature to which air can be cooled by evaporation is the wetbulb T.
- Find LCL & Take moist adiabat down from there to $p = 1000\text{ hPa}$ (assume for arizona)

$T_{wb} = 18°C$ (64°F)

(3.) B&A, Ch6, #6 $T_d = 75°F = 23.9°C$

$T = 95°F = 35°C$

Using the same procedure as for (2.), $T_{wb} = 27°C$ (80°F)

The dewpoint makes a huge difference.

(4.) B&A, Ch6, #8 $\Theta_v = \left(\frac{p_0}{p}\right)^{(\gamma-1)/\gamma}(T + 0.608q)$

$\Theta_v = \Theta + \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}} 0.608q.$

For a fixed p, take the derivatives with respect to z.

$\frac{d\Theta_v}{dz} = \frac{d\Theta}{dz} + 0.608\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}\frac{dq}{dz}$. If $\frac{dq}{dz} < 0$, then

$\frac{d\Theta_v}{dz} < \frac{d\Theta}{dz}$. But $\frac{d\Theta_v}{dz}$ gives real stability. So

$\frac{d\Theta}{dz}$ predicts a <u>more</u> stable atmosphere than exists.

(5.) B&A, Ch6, #22. $p_0 = 850\,hPa$, $T = 10°C$ $RH = 100\%$

a. Since RH = 100%, go up the moist adiabat to 600 hPa. $w_i = 9\,g/kg$. At 600 hPa, $w_s = 4.2$, so that $w_w = 9 - 4.2 = 4.8\,g/kg$. Assume this is removed.

b. If all liquid is removed, $p = 600\,hPa$ is the new LCL. Go down constant w & θ to 850 hPa. Now $T = 23°C$ and $RH = \frac{4.2}{20} = 21\%$ warm & dry.

(6.) B&A, Ch6, #24.

In a cloud, the relative humidity is 100% and liquid water exists. Below the cloud, the relative humidity can be below 100%. Rain falling out of the cloud into the lower RH air starts to evaporate, but can hit the ground before all or much of it has evaporated.